RCM AT SOBRANTE WATER TREATMENT PLANT:
WHAT DID WE FIND AND WHERE DO WE GO FROM HERE?

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Introduction

The East Bay Municipal Utility District (EBMUD) completed a reliability-centered maintenance (RCM) analysis at Sobrante Water Treatment Plant, a 60-million gallon per day conventional water treatment plant. The process took two years and involved numerous operations and maintenance personnel as well as an engineer. This paper will explore results of the RCM analysis and implementation issues encountered at Sobrante Water Treatment Plant.

EBMUD supplies water to 1.3 million people in the San Francisco Bay Area and employs over 200 people in the Maintenance Support Division (approx. 2100 people total). The water system includes 5 water treatment plants, 143 pumping plants, 216 reservoirs, and 4,000 miles of pipeline.

EBMUD's RCM Analysis and Methodology

The primary purposes of EBMUD's RCM program are to:

- Right-size maintenance staffing; and
- Identify regulatory and safety shortcomings; and
- Bring operations and maintenance personnel to a common understanding of asset and system functions.

During EBMUD's RCM process, individual system components were identified and analyzed following basic RCM principles. Preventive maintenance (PM) tasks were identified, and job plans (step-by-step PM task descriptions) were prepared. Afterwards, the PM tasks and job plans were then entered into the computerized maintenance management system (MAXIMO). Additionally, as part of EBMUD's Asset Management Program, each asset (including all valves, pumps, instrumentation, etc.) was assigned an identification number, physically tagged in the field, and revised accordingly on the drawings (approximately 3,100 components total).

EBMUD divides the RCM analysis into 5 main segments: 1) Process and data collection, 2) Criticality/Failure Modes and Effects analysis, 3) Predictive and preventive maintenance task development, 4) Step-by-step job plan development, and 5) Implementation. Meetings are held as each of the first four stages of the RCM analysis. A Resource Team specific to each system is identified; the team consists of one maintenance representative (subject matter expert) from each of the trades (usually mechanical, electrical, and instrumentation), a representative from operations, a representative from the regulatory compliance group, and an engineer who serves as a facilitator and "record keeper".

During the data collection step, the Engineer looks for any available drawings and walks through the system in the field. A process meeting is held with the Resource Team to gather process information, to ask questions about the system functionality and process, and to verify system boundaries.

Next, the Resource Team meets to verify system component failure modes, causes, and plant effects and determines critical and non-critical components based on the failure analysis. A component is defined as critical if its failure affects:

- Production – Failure to meet seasonal requirements
- Quality – Water quality degradation
- Regulatory – California Department of Health Services violation or process target exceedance
- Safety – Injuries or fatalities

The next step is to identify preventive and predictive maintenance tasks and frequencies for all components based on failure modes and effects. Detailed step-by-step instructions (i.e. job plans) are then developed for each recommended PM task.

Finally, the RCM database and job plans are imported into our computerized maintenance management system for implementation. The information entered into the computerized maintenance management system includes the following for EACH component: equipment identifier and description, failure mode and effect, critical or not critical, vendor information (make and model), replacement cost, any parent/child relationship, location identifier, and PM task(s) or run-until-failure. Additionally if maintenance on a component requires that the WTP or the system needs to be shut down, a flag is added to that work order. Also, every component is physically tagged with a plastic laminate tag in the field, and as-built drawings are created.

Details of Sobrante Water Treatment Plant

The Sobrante Water Treatment Plant (WTP) was built in 1964 with a design capacity of 60 million gallons per day (mgd). In 1991, several improvements were made, including construction of ozonation facilities, new chemical feed systems, new chemical storage tanks, and a new chemical building.

Sobrante WTP receives water from a local reservoir. The current treatment process consists of aeration, raw water rapid mix, flocculation, coagulation, sedimentation, ozonation, applied water rapid mix, filtration, and chemical post-treatment. Current chemical feed systems include sodium hypochlorite, ammonia, fluoride, caustic soda, potassium permanganate, polymer, and alum. Plant flow rates have historically varied between 10 and 40 mgd with an average flow of 26 mgd.

For the RCM analysis, the WTP was divided into the following systems:

- Outlet Tower (WTP intake location at the local reservoir)
- Chemical Systems – Phase 1 (caustic soda, alum, ammonia, fluoride, heating/ventilation/air conditioning for Chemical Building)
- Chemical Systems – Phase 2 (sodium hypochlorite, polymers, lab/analyzers)
- Ozone System
- Raw Water Treatment (rapid mix, flocculation, sedimentation)
- Filtration
- Filter Backwash/Reclaim
- Emergency Generator
- Electrical Distribution System (motor control centers, transformers, switchgear, etc.)

What Did We Find?

Summary

Of the approximately 3,100 total components at Sobrante Water Treatment Plant, over 1,850 were included in EBMUD's RCM analysis. The remaining components were considered outside of the system boundaries and included such items as manual hand valves. Approximately 20% of the RCM components were identified as critical, and approximately 80% were found to be non-critical. Approximately 2,100 maintenance tasks were identified, which included over 500 checks for operators to perform on their rounds.

In general, EBMUD has a great deal of redundancy within Sobrante WTP and throughout the other facilities as well. It was established 80 years ago as a municipal utility district that supplies high quality drinking water to its customers and does not allow for water shortages or outages to customers (except in a drought). As such, there are generally redundant pieces of equipment installed in line to allow for operational and/or maintenance outages during regular operation.

The Operations and Maintenance personnel, although not enthused about attending long RCM meetings, are very willing to share their extensive knowledge and ideas. Having all subject matter experts together in the meeting has been extremely beneficial. The results make for a very good RCM analysis, but also have led to a great deal of knowledge sharing and cooperation among maintenance personnel and operators. Sometimes maintenance personnel were maintaining a component that operations was no longer using or Operators were relying on equipment that was not part of the maintenance program. Open discussion among Resource Team members at the RCM meetings clarified such issues and others.

The before and after preventive/predictive maintenance (PM/PdM) hours on each system are as follows:

	Before RCM	After RCM	Percent Change
• Outlet Tower	38	49	30%
• Chemical Systems (all)	759	813	7%
• Ozone	324	138	-58%
• Raw Water Treatment	26	24	-10%
• Filtration	176	180	2%
• Filter Backwash/Reclaim	62	110	75%
• Emergency Generator	24	103	76%

The instrumentation hours for the ozone system decreased by 58% due to the elimination of numerous unnecessary tasks. One such task was calibrating pressure and flow gauges that were no longer used or were most cost-effective to simply replace if they failed.

The machinist hours for the reclaim system appeared to increase by 75%; however, “before” hours were incorrectly recorded in MAXIMO (for example, 0.25 hours was shown for a task that typically takes 8 hours). In addition, the machinist is currently not doing any preventive maintenance tasks due to lack of time. Therefore, the 75% “increase” is not a realistic look at what RCM is actually accomplishing. This case illustrates the difficulty in before and after quantitative hourly comparisons.

The electrician hours for maintenance of the emergency generator and electrical distribution system at Sobrante WTP increased significantly because very little maintenance was being performed on this equipment. Much of it is 30-40 years old and is in need of regular cleaning and inspection at a minimum.

The PM/PdM hours for the remaining systems remained approximately the same after the RCM analysis, although many hours shifted among disciplines and many PM tasks changed. Hours for operator rounds are not included in the above numbers.

Predictive Maintenance and Condition-Based Monitoring

Several tasks recommended as part of the RCM analysis relate to predictive maintenance and condition-based monitoring tasks. A pilot program is in progress at Sobrante WTP that is evaluating current and future predictive maintenance and condition-based monitoring tasks. EBMUD had been doing some predictive maintenance tasks (e.g. vibration monitoring), but most of the predictive maintenance and condition-based monitoring work tasks are new to EBMUD and, therefore, require equipment budgeting and purchasing as well as personnel training.

Predictive Maintenance
As part of the RCM implementation, EBMUD purchased 2 thermography cameras, provided training, and started a thermography program for electrical equipment. Recently during a PM task at a nearby WTP, it was discovered that breakers that feed the Uninterruptible Power Supply that power the filter control system were overload by 31%. If these overloaded breakers were not discovered during this PM, failure could have caused the WTP to shut down, creating major water service problems and/or water outages for customers. Discovering and correcting this problem before it “failed” prevented a potential WTP outage and protected personnel.

EBMUD has already been successfully performing vibration analysis on various pieces of equipment (primarily pumps at the WTPs and at the pumping plants). One pump at EBMUD’s Los Altos Pumping Plant was gradually showing signs of a problem due to increased vibration. After several months, that pump was taken out of service (planned at an acceptable time when the pumping plant could operate with one less pump), and a faulty bearing was discovered. The problem was corrected, and the pump was reinstalled without a disruption to service. As part of the pilot project, EBMUD will verify the effectiveness of vibration monitoring on smaller pumps and motors throughout the service area.

Oil analysis is being investigated as a tool to better predict problems and/or potential failures of pumps, blowers, and compressors. Oil sampling ports are being installed on 3 large compressors, 2 large blowers, and some smaller blowers and clarifier scraper arms at Sobrante WTP. Oil samples will be taken over the next year to determine where/how it could be used most effectively (to condition direct oil changes for equipment that requires large amounts of oil and/or to find other equipment problems).

Condition-Based Monitoring and Operator Rounds
Operator rounds were developed during the RCM process. The rounds consist of various condition-based monitoring and equipment checks as well as some data collection. A feasibility analysis is underway as part of the Pilot Program to evaluate the use of a handheld computer or a tablet PC to collect rounds data. An operator then could theoretically check items off while doing rounds around the WTP, enter appropriate data and readings, and generate corrective work orders all from a handheld computer. Data collected that is out of a specified “normal” range would be flagged, and web-based reports would be created showing rounds completed, “problem” items found, and data collected.

There are also other preventive/predictive maintenance tasks that include feedback, data collection, and trending (e.g. insulation resistance checks performed by electricians). EBMUD is working on ways to effectively collect, store, and trend data either within MAXIMO or in other programs. The data that is collected needs to be used (why collect data that no one looks at?) and it needs to be accessible for all levels from managers to technicians The current approach is to use a separate program that is accessible from EBMUD’s internal intranet. This approach would allow many different people and groups to view and analyze the data. Field personnel could still have some problems accessing the data because wireless coverage for their laptop computers is not available at all EBMUD facilities, and the data transmission speed can be slow.

Other Reliability Issues

Other issues came up during the RCM analysis that could not be addressed by maintenance. Some of these issues resulted in design changes or equipment replacement, while others required stocking of spare parts.

Design Changes
Part of the implementation of RCM also included instituting various design changes to correct potential operational deficiencies and to address potential failures that could not be taken care of with maintenance. For example, an ambient air analyzer in the ozone generation room had an air pump with a hidden failure. Personnel entering the room did not know if that analyzer and associated air pump were functioning properly unless they walked through the room to the analyzer to inspect it. An alarm was added to activate when the air pump was not working, and maintenance tasks were added to periodically check the alarm.

Equipment Replacement
Some equipment was found to be unreliable or required frequent maintenance. In some situations, maintenance and operations personnel were accustomed to frequent maintenance and/or breakdowns, and therefore did not consider replacement. For example, a chemical tank high level sensor (8 total) required 16 hours of annual maintenance to ensure it functioned as expected. The sensors were 10 years old and used "old technology", and, after some research, the sensors were replaced with a more reliable sensor using current technology that requires very little maintenance (possibly cleaning the probe annually, depending on how much chemical residue builds up), thereby saving at least 12 hours per year.

Spare Parts
For some equipment that was identified as critical but had no maintenance tasks that could prevent failure, spare parts and/or equipment was purchased. In some cases, spare equipment and/or parts were also purchased for non-critical components that had long lead times or required special orders. Most of the spare parts purchased were for electrical components that would shut down the WTP if they failed. The spare parts were catalogued and are now stored in a locked cabinet at the WTP site. Having critical spare parts located physically at the WTP site and not at the general EBMUD warehouse located an hour away saves precious time when a critical component fails.

Implementation Issues

Various implementation issues arose after each RCM analysis was completed:

- Job plan development
- Maintenance planning for water treatment plant shutdown
- Equipment hierarchy/cost rollup preparation
- Living Program development

Job Plan Development
Before RCM was started at EBMUD, most job plans were general in nature and were written to an entire facility instead of to a particular component. This made it difficult (if not impossible) to track specific preventive maintenance tasks performed on particular components.

Job plan development was initially not part of the Engineer's duties. However, it soon became apparent that writing the job plans (step-by-step PM task instructions) helped better define PM tasks. It also helped identify some required testing equipment that was needed (for high temperature shutdown switches on the ozone air compressors, for example) and revealed some component access problems (in one case, a temperature transmitter was not accessible because insulation was installed just above it).

Maintenance personnel wrote the step-by-step job instructions together with the Engineer usually at a laptop computer. The goal is to write as many standardized job plans as possible. For example, there are hundreds of identical flow transmitters throughout EBMUD's facilities. The steps involved in calibrating a flow transmitter are essentially the same. Some locations may need more frequent calibration or cleaning, and this is taken into account. But, in general, the intent is to have maintenance personnel performing the same calibration steps across all of EBMUD's facilities.

There is another "driver" in documenting the step-by-step job instructions: retirement. The average age of EBMUD employees is 47, and in 2004 alone, over 70 people are eligible for retirement. Over the next fifteen years, over 1200 people will be retiring (that's more than half of our workforce!). The machinist who had been at Sobrante WTP 10+ years and with EBMUD 25 years retired after the Sobrante WTP RCM analysis was completed. Having his knowledge, input, and ideas during the RCM process was invaluable. It is extremely beneficial to have this type of on-the-job knowledge documented as much as possible.

To illustrate the differences in a job plan before RCM and a job plan after RCM, see Figure 1.

Water Treatment Plant Shutdown
When RCM was started at Sobrante WTP, the WTP was not regularly taken out of service and was occasionally taken only out as needed at times during the winter months. Several maintenance tasks (particularly electrical inspections and tasks associated

with the 60" WTP inlet valve) were identified that require the WTP be out of service. As a result, there is now an annual shutdown scheduled. Preventive maintenance tasks that require the WTP be out of service are flagged in MAXIMO; when exact shutdown dates are scheduled, preventive maintenance work orders are generated. This level of planning and coordination did not previously exist to this degree and is quite beneficial.

Equipment Hierarchies/Cost Roll-ups

Another change that evolved during implementation of RCM was the way preventive maintenance (PM) tasks were written and stored in MAXIMO. Whereas "old" PM tasks were written to groups of equipment or entire facilities, the "new" PM tasks are written to each component, thereby creating the illusion of more PM tasks and creating more pieces of paper. The Engineer created equipment hierarchies for each system to show relationships among components and systems (see Figure 2), allowing for cost rollups within the Maintenance Program. Maintenance personnel are unhappy with the additional paperwork, but education of the Maintenance personnel is ongoing to explain the benefits of this approach (i.e. it allows tracking of failures and maintenance tasks at an equipment level instead of a facility level).

The next step with the cost roll-ups is to include the cost of parts on each preventive maintenance work order and each corrective work order. Improved cost tracking will help identify actual maintenance costs and areas of needed focus.

Living Program

This RCM/Asset Management program is a living program and, as such, the Engineers have been receiving a fair amount of feedback after preventive maintenance tasks are performed. Maintenance personnel have been suggesting improvements to job plans and coming up with improved methods of performing various preventive maintenance tasks. This feedback is vital to the maintenance program, and the Engineers are working on better ways to capture this information (e.g. some personnel provide too much feedback, while others don't provide enough). Operations and maintenance personnel feel a level of comfort with the living program knowing that the Engineers are in-house and available after the RCM analysis is done.

Where Are We Going?

RCM will continue at all new and existing EBMUD facilities, including the remaining 4 water treatment plants, 143 pumping plants, and 216 reservoirs. There is currently an effort underway to streamline the process. It now takes 2-4 months to do a complete RCM analysis on an average system (200 components). However, during that time, the Engineers are accomplishing much more than an RCM analysis: preparing step-by-step job plans, identifying and tagging equipment, determining vendor and model information, updating drawings to reflect as-built conditions, estimating replacement costs, defining hierarchies and cost rollups, and working with the living program aspects of RCM (comments/thoughts/ideas on previous PM tasks and job plans). Streamlining could involve other junior engineers in some data collection and tagging aspects of each system or it may involve deleting some of the above "extras" from EBMUD's RCM process.

There are other items under currently under development:

§ The Predictive Maintenance and Condition-Based Monitoring Pilot Project will be completed within the next 6 months. Recommendations for new procedures such as oil analysis will be introduced together with the necessary budget for equipment and training. Included in this project is the possible implementation of computer-based operator rounds.

§ The Engineers will continue to work with operations and maintenance personnel to gain their "buy-in" and work through implementation issues. Change is hard, and it is important that everyone understands and works toward the goals of EBMUD's RCM and Maintenance Program.

§ Equipment is constantly being changed or added throughout EBMUD's facilities via replacement and new construction. There is a need to conduct a "mini-RCM" and determine maintenance (if any) for the new equipment being added. The current process is fairly informal, but needs to be formalized so that equipment is not put into service without necessary maintenance.

§ Key performance indicators are being developed to evaluate the effectiveness of the RCM and the Maintenance Program. The first step is to properly document all of the costs associated with each corrective and preventive work order. Secondly, realistic and measurable performance indicators need to be determined. Some initial indicators being considered are: number of failures captured by predictive/condition-based monitoring tasks and number of unmitigated failures on critical equipment.

Figure 1A – Sample Job Plan for Flow Transmitter BEFORE RCM

SOBRANTE WTP, 6-MONTH EFFLUENT FLOW TRANSMITTER CALIBRATION

1. Blow down.
2. Clean.
3. Calibrate.

Instrument Technician Labor Hours: 1 Craft Quantity: 1

Figure 1B – Sample Job Plan for Flow Transmitter AFTER RCM

SOB FILTRATION, ANNUAL FLOW TRANSMITTER CALIBRATION
FLOW TRANSMITTER ON EACH FILTER

1. Notify operations that filter effluent valve will remain at current position during this PM.
2. Put valve control system in manual.
    a. Inside Instrument Control Panel that contains the VersaValves for individual filter, put effluent valve selector switch in “manual”.
3. Open and close appropriate valves to blow down and remove sand if necessary by rodding out. Blow down lines. Verify proper water flows. If necessary, remove fittings.
4. Drain Transmitter for dry calibration.
5. Perform 5 point calibration of transmitter.
6. Record results on Flow Transmitter Calibration Form.
7. Return transmitter to service and bleed lines.
8. Apply updated calibration sticker with appropriate dates and initial.
9. Turn in flow calibration sheet to supervisor with completed PM form.
10. Return to automatic control by putting valve selector switch in “remote” at Local Control Panel.
11. Verify and adjust zero with no flow condition (filter will have to be out of service).

Instrument Technician Labor Hours: 2 Craft Quantity: 1

Figure 2 – Sample Equipment Hierarchy